A Record of Lateglacial and Early Holocene Environmental and Ecological Change from Southwestern Connecticut, USA

A record of late-glacial and early-Holocene environmental and ecological change from southwestern Connecticut, USA

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Abstract

Analyses of a sediment core from Highstead Swamp in southwestern Connecticut, USA reveal late-glacial and early-Holocene ecological and hydrological changes. Late-glacial pollen assemblages are dominated by *Picea* and *Pinus* subg. *Pinus*, and the onset of the Younger Dryas (YD) cold interval is evidenced by higher abundance of *Abies* and *Alnus viridis* subsp. *crispa*. As climate warmed at the end of the YD, *Picea* and *Abies* declined and *Pinus strobus* became the dominant upland tree species. A shift from lacustrine sediment to organic peat at the YD-Holocene boundary suggests that the lake that existed in the basin during the late-glacial interval developed into a swamp in response to reduced effective moisture. A change in wetland vegetation from *Myrica gale* to *Alnus incana* subsp. *rugosa* and *Sphagnum* is consistent with this interpretation of environmental changes at the beginning of the Holocene.

Introduction

Environmental and ecological changes associated with the Younger Dryas (YD) climatic oscillation (12,900-11,600 calibrated ^{14}C years before present; cal yr BP) have been studied at many sites in eastern North America using a variety of approaches (e.g., Peteet et al., 1990; Levesque et al., 1993; Mayle et al., 1993; Cwynar and Levesque, 1995; Shemesh and Peteet, 1998; Yu and Eicher, 1998; Lavoie and Richard, 2000; Newby et al., 2000; Cwynar and Spear, 2001; Huang et al., 2002; Shuman et al., 2001, 2002; Hou et al., 2007; Lindbladh et al., 2007; Yu, 2007). Pollen records typically feature an increase in cold-tolerant taxa at the beginning of the YD and a shift to taxa indicative of warmer conditions at the YD-Holocene boundary (e.g., Shuman et al., 2002). Quantitative reconstructions of temperature for this interval yield generally consistent results, indicating ~5°C shifts at the beginning and end of the YD (Shemesh and Peteet, 1998; Yu et al., 1998; Cwynar and Spear, 2001; Yu, 2007). Late-glacial changes in moisture balance, on the other hand, have received less study. Lake-level reconstructions from southern Québec (Lavoie and Richard, 2000) and southeastern Massachusetts (Newby et al., 2000; Shuman et al., 2001) indicate relatively wet conditions during the YD and drier climate at the beginning of the Holocene, but other records of moisture-balance shifts associated with the YD have not been developed. In this paper we report on a late-glacial sedimentary record from a swamp in southwestern Connecticut, USA. Analyses of pollen and organic content provide additional insights into changes in moisture balance at the end of the YD.

Study Area

Highstead Swamp (41° 19.5' N, 73° 23.75' W) is located at Highstead, a 150-acre woodland preserve in Redding, Connecticut. This area of southwestern Connecticut falls within the Northeastern Coastal Zone, an ecoregion that extends across southern New England (Griffith et al., 1994).

The swamp is part of a 4-ha seasonally flooded basin; it has an intermittent outlet stream that drains into a 1-ha artificial pond before continuing to the southeast. Soils range from muck to poorly drained and stony (Wolf, 1981). The swamp is bounded to the west by a rugged northeast-to-southwest trending ridge of Ordovician-age schist and granitic gneiss; to the east is a smooth, northwest trending drumlin composed of Wisconsinan glacial till overlying Illinoian till (Rodgers, 1985; Stone et al., 2005). The vegetation of the swamp features *Acer rubrum* and *Betula alleghaniensis* in the overstory, *Clethra alnifolia*, *Lindera benzoin*, and *Ilex verticillata* in the understory, and a ground layer of *Symplocarpus foetidus*, *Osmunda cinnamomea*, and *Carex* species. Dry, upland forest to the west consists of 70-90 year old *Quercus rubra*, *Q. coccinea*, and *Q. prinus*, with dense *Kalmia latifolia* in the understory. To the east, moist *Acer rubrum*, *Fraxinus americana*, and *Liriodendron tulipifera* forest (45-85 years old) occurs on fine-grained soils. The *Quercus* forest was continuously forested during the European settlement period but was cut heavily for wood products, while the *Acer-Fraxinus* forest was open pasture during the settlement period and reverted back to woodland only in the twentieth century.

Methods

We collected a sediment core from Highstead Swamp in June of 2006. We accessed the center of the swamp using an established boardwalk and collected a 256-cm-long core using a modified Livingston piston sediment sampler. Core segments were extruded horizontally in the field, wrapped in plastic and aluminum foil, and subsequently refrigerated.

The analyses presented here were performed on the interval of the core from 256 to 94 cm; the upper interval of the core appeared to be disturbed and therefore was not analyzed. Sediment samples of 1 cm^3 were prepared for pollen analysis following standard procedures (Faegri and Iversen, 1989), and tablets containing *Lycopodium clavatum* spores were added during processing to allow calculation of pollen and spore concentrations (Stockmarr, 1971). Pollen residues were mounted in silicone oil and analyzed at 400x magnification. At least 500 pollen grains and spores of upland plant taxa were counted for each sample, and pollen percentages were calculated relative to that sum. *Myrica*-type pollen, which is very abundant in samples from 134 and 138 cm, was not included in the sum used to calculate percentage values.

Sediment organic content was estimated for 1-cm^3 samples at selected depths by percent weight loss-on-ignition (LOI) at 550 °C.

Chronological control is provided by accelerator mass spectrometry ^{14}C analysis of four woody plant macrofossils sieved from the sediment (Table 1). Dates were converted to calibrated ^{14}C years before present (cal yr BP) with CALIB 5.0 (Stuiver and Reimer, 1993). The date of the uppermost sample (~11,900 cal yr BP; 109 cm) is inconsistent with the age-depth relationship of the other dates and data from other sites, and is therefore rejected.

Results

The lower section of the core (256-210 cm; ~13,300-13,000 cal yr BP) is lacustrine sediment featuring pollen assemblages dominated by *Picea* (~30%) and *Pinus* subgenus *Pinus* (~30%), with minor abundances of *Ostrya-Carpinus*, *Fraxinus*, *Quercus*, *Betula*, Poaceae, Cyperaceae, and pteridophytes (Fig. 2). Organic content increases from ~50 to 60% during this interval (Fig. 3). Various changes occur after ~13,000 cal yr BP (220-200 cm), including increased abundance of *Abies*, *Alnus*, *Nuphar*, and *Myrica*-type and decreasing percentages for *Ostrya-Carpinus*, *Fraxinus*, *Quercus*, Poaceae, and pteridophyes (Fig. 2-3). Organic content declines abruptly between ~220 and 200 cm, then increases from ~50 to 70% between 200 and 140 cm. The upper section of the core (140-90 cm; <11,500 cal yr BP) changes abruptly to peaty sediment, with organic content increasing from ~70 to 90%. This interval has a dramatic decline in *Picea* pollen percentages (~30 to <5%) and a corresponding rise in *Pinus* subgenus *Strobus* abundance (~5 to 60%). *Abies* abundance declines above 140 cm, whereas *Tsuga* pollen reaches ~2-3% and *Alnus* pollen peaks at ~40%. *Myrica*-type pollen becomes very abundant in samples at the beginning of this transition (Fig. 3), just before the peak in *Alnus* pollen percentages, while *Sphagnum* spores reach a peak coincident with the highest *Alnus* values.

Discussion

The changes observed in the Highstead Swamp record at ~13,000 cal yr BP, including declining percentages of *Ostrya-Carpinus* pollen and higher abundances of *Abies* and *Alnus* (presumably *A. viridis* subsp. *crispa*), are consistent with pollen data from sites in southern New England (e.g., Davis, 1969; Suter, 1985; Lindbladh et al., 2007) and elsewhere in eastern North America (e.g., Mayle et al., 1993; Peteet et al., 1993). The ~5°C drop in temperatures at the beginning of the YD (Shemesh and Peteet, 1998; Yu et al., 1998; Cwynar and Spear, 2001; Yu, 2007) appears to have shifted vegetation assemblages across the region towards cold-tolerant taxa (Shuman et al. 2002), although some ecological changes may have been underway in advance of the onset of YD cooling (Lindbladh et al., 2007).

The end of the YD cold interval in the Highstead Swamp record is also marked by changes in vegetation seen at other sites. *Picea* pollen percentages decline abruptly at ~11,500 cal yr BP, and boreal taxa such as *Abies* are replaced by temperate taxa including *Pinus strobus*, *Tsuga canadensis*, and *Quercus* (e.g., Mayle et al., 2003; Shuman et al. 2002; Lindbladh et al., 2007). A comparison of pollen and paleoclimatic data by Williams et al. (2002) indicates that vegetation responded quickly to rising temperatures at the beginning of the Holocene. The peak in *Alnus* pollen percentages at the YD-Holocene boundary in the Highstead Swamp record, however, is not a feature that is normally observed in other pollen records from eastern North America (but see Newby et al., 2002). In fact, the decline of *Alnus* is typically seen as a distinguishing marker of the end of the YD (Mayle et al., 1993). We interpret the increase in *Alnus* abundance, as well as the rise in *Myrica*-type pollen occurring just prior to the *Alnus* peak, as evidence for changes in the composition of the local vegetation in response to a shift in moisture availability and hydrological conditions at the beginning of the Holocene.

Several lines of evidence from the Highstead Swamp record indicate a sequence of hydrological and ecological changes during the transition from the YD to the Holocene. The decline in the abundance of *Nuphar*, an aquatic plant, and shift from lacustrine sediment to peat suggest that the lake that occupied the basin during the late-glacial interval became a swamp after ~11,500 cal yr BP. A similar transition in the sediments of Makepeace Cedar Swamp, located in southeastern Massachusetts, was also interpreted as a shift from lake to swamp at the beginning of the Holocene (Newby et al., 2000). The changes in wetland vegetation at Highstead Swamp are consistent with this interpretation. The wet substrate of the swamp was initially dominated by *Myrica gale*, as evidenced by the high abundance of *Myrica*-type pollen, and subsequent development of the swamp likely allowed *Alnus* and *Sphagnum* to become prevalent. We suspect that the *Alnus* pollen represents the presence of *Alnus incana* subsp. *rugosa*, which can occur with *Sphagnum* in bogs and swamps in eastern North America (e.g., Cronan and DesMeules, 1985).

Taken together, the changes observed in the sedimentary record from Highstead Swamp are consistent with lake-level studies from eastern North America (Lavoie and Richard, 2000; Newby et al., 2000; Shuman et al., 2001), which suggest that water levels declined ~11,500 cal yr BP in response to declining effective moisture. Those dry conditions prevailed in New

England until ~8000 cal yr BP, when the deterioration of the Laurentide Ice Sheet brought wetter climate to the region (e.g., Shuman et al., 2006).

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Table 1. Results of ^{14}C dating for Highstead Swamp

Depth (cm)	Material	Lab number	$\delta^{13}C$	^{14}C age ± error	Cal range (2σ)	Median cal age
109-110*	Wood	OS-59498	-27.63	10,200 ± 35	11,760-12,050	11,910
142-143	Wood	OS-59484	-26.90	10,000 ± 50	11,270-11,710	11,480
209-210	Wood	OS-59499	-28.31	11,100 ± 50	12,910-13,110	13,010
257-258	Wood	OS-59500	-25.83	11,450 ± 50	13,210-13,410	13,300

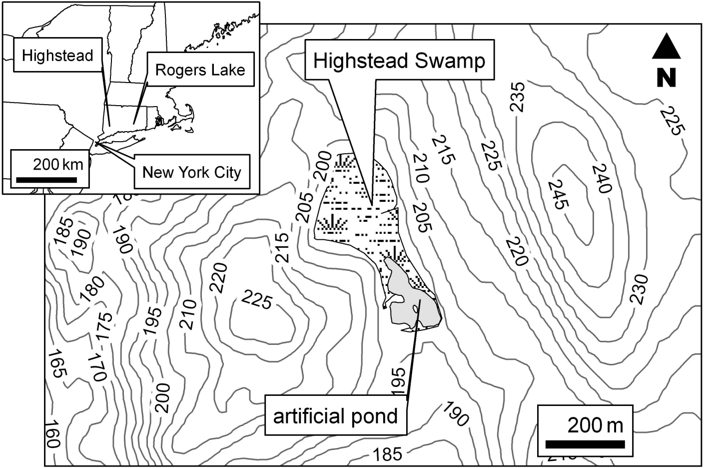
*Rejected due to age reversal

Figure captions

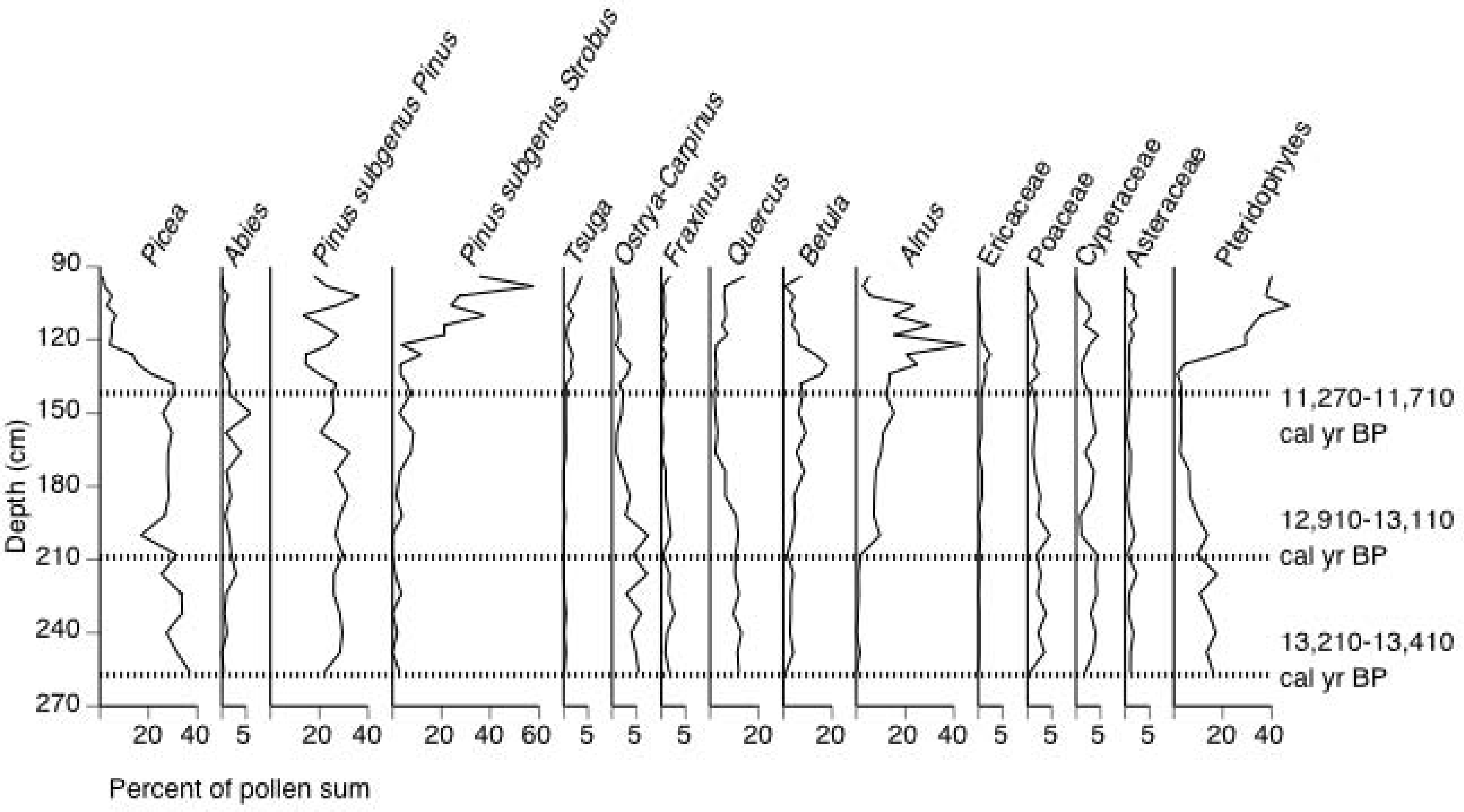
Figure 1. Map of the Highstead Swamp and surrounding topography in Redding, Connecticut, USA. Inset map shows location of Rogers Lake (Davis, 1969).

Figure 2. Pollen percentage diagram for selected taxa from the Highstead Swamp sediment record. Note changing scale for x-axes. Horizontal lines are depths of ^{14}C samples; the 2σ calibrated ^{14}C age ranges are shown.

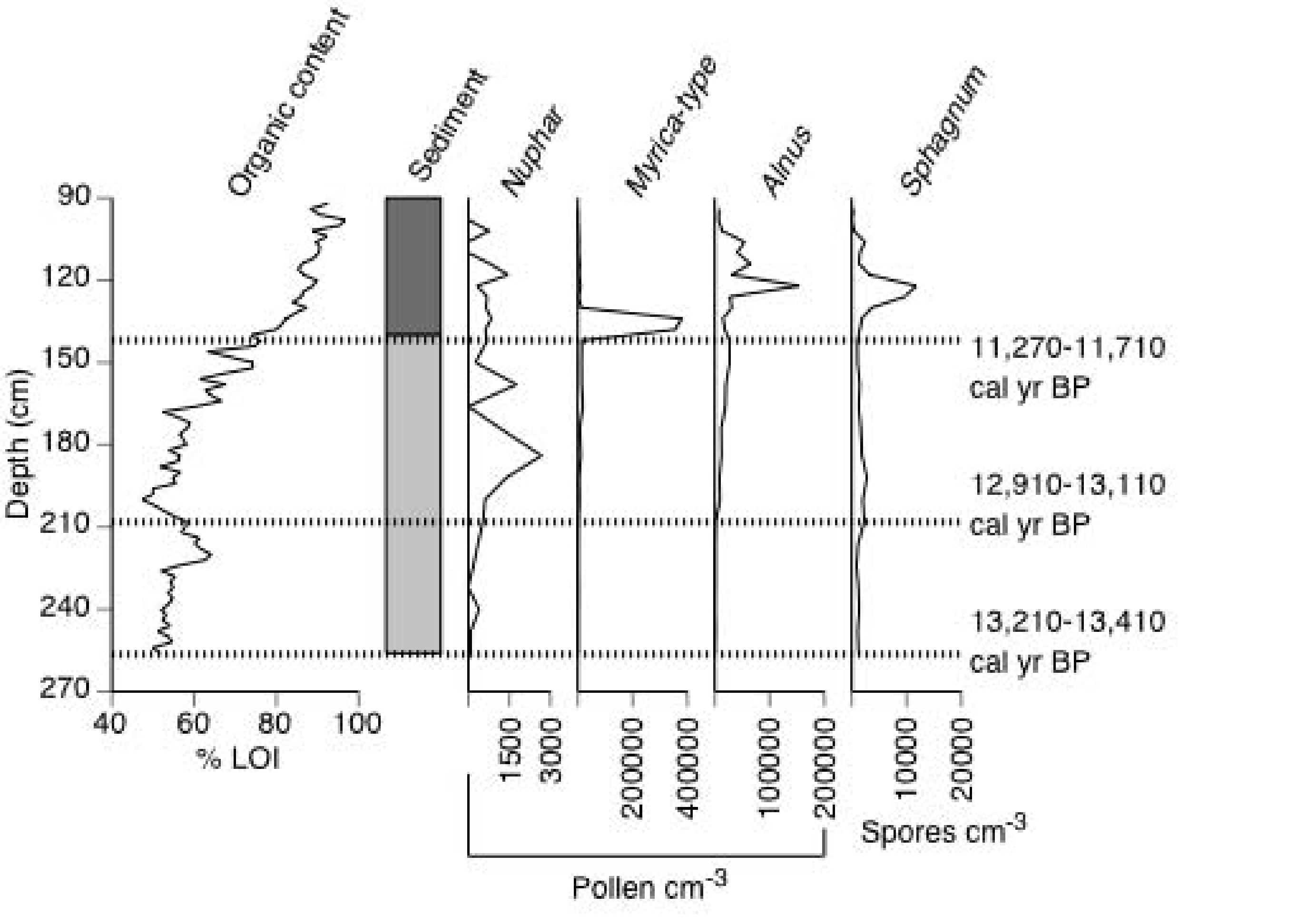
Figure 3. Organic content (percent weight loss-on-ignition; % LOI), sediment characteristics (light gray is lacustrine sediment, dark gray is peat), and pollen and spore concentrations for selected taxa from the Highstead Swamp sediment record. Note changing scale for x-axes. Horizontal lines are depths of ^{14}C samples; the 2σ calibrated ^{14}C age ranges are shown.



Highstead
Rogers Lake
New York City
200 km
Highstead Swamp
N
artificial pond
200 m



Picea
Abies
Pinus subgenus Pinus
Pinus subgenus Strobus
Tsuga
Ostrya-Carpinus
Fraxinus
Quercus
Betula
Alnus
Ericaceae
Poaceae
Cyperaceae
Asteraceae
Pteridophytes
Depth (cm)
90
120
150
180
210
240
270
11,270-11,710 cal yr BP
12,910-13,110 cal yr BP
13,210-13,410 cal yr BP
20 40
5
20 40
20 40 60
5
5
5
20
20
20 40
5
5
5
5
20 40
Percent of pollen sum


Organic content
Sediment
Nuphar
Myrica-type
Alnus
Sphagnum
Depth (cm)
90
120
150
180
210
240
270
40
60
80
100
% LOI
1500
3000
200000
400000
100000
200000
10000
20000
Spores cm-3
Pollen cm-3
11,270-11,710 cal yr BP
12,910-13,110 cal yr BP
13,210-13,410 cal yr BP